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13. Abstract ***(Maximum 200 Words)*** *(abstract should contain no proprietary or confidential information)*

Mammography plays an important role in the detection and diagnosis of breast cancer. Although computer-aided detection (CAD) scheme is essential and acts as second opinion for the detection and diagnosis of breast cancer, its performance for SFM is not suitable for clinical trial due to the lack of full optimization for CAD system. In addition, current CAD system is not evaluated on FFDM images. The purpose of this study is to develop a new kind of fully optimized CAD system for FFDM using a global optimization algorithm to improve its performance on sensitivity and specificity in mass and MCCs detection on mammograms.

In the initial grant year, the major accomplishments are as follows:

(1) Databases for training and testing of CAD system performance have been constructed and corresponding truth files have been generated for FFDM and SFM respectively.
(2) Performance of current CAD system for the detection and diagnosis of breast cancer has been retrospectively evaluated on FFDM and SFM images, respectively.
(3) CAD modules have been developed or modified for FFDM.

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Annual Report:

Optimization of CAD System Using Adaptive Simulated Annealing for Digital Mammography

INTRODUCTION

Mammography plays an important role in the detection and diagnosis of breast cancer. Conventional screen-film mammography (SFM) has been proved to have limitations in detecting all breast cancers in undergoing regular screening mammography. A new technique for breast imaging, full-field digital mammography (FFDM), is said to have potential to detect more breast cancers or to detect them at smaller sizes and earlier stages, but its performance needs clinical verification. Although computer-aided detection (CAD) scheme is essential and acts as second opinion for the detection and diagnosis of breast cancer, its performance for SFM is not suitable for clinical trial due to the lack of full optimization for CAD system. In addition, current CAD system is not evaluated on FFDM images. The purpose of this study is to develop for the first time a new kind of fully optimized CAD system for FFDM using a global optimization algorithm to improve its performance on sensitivity and specificity in mass and MCCs detection on mammograms.

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The research work of initial grant year has been accomplished successfully following the approved statement of work and progressed smoothly without technical or unexpected difficulties.

KEY ACCOMPLISHMENTS IN INITIAL GRANT YEAR

1. Databases construction

Databases are planned for optimization and evaluation of CAD systems on different imaging paradigms: FFDM and SFM. In addition, they are designed for the comparison of CAD system performance between FFDM and SFM. 200 FFDM cases came from DMR2000D of GE installed in the institute in 1999 with spatial resolution of 100μm and 16 bits gray value. 200 SFM Cases (from DBA and Lumisys digitizer) have been selected from the Department of Defense (DoD) Breast Cancer Research Program (BCRP) grant to the University of South Florida (USF) (http://marathon.csee.usf.edu/Mammography/Database.html) with resolution of 40-50μm and 16 bits gray value.

In the generated databases of each kind of imaging paradigm, one database is for training and another one is for testing and evaluating CAD system performances. They are selected randomly.

2. Generation of truth files for databases

The truth files for every image in databases have been generated based on the analysis of medical Radiologists and clinically biopsy results, which are for the retrospective studies for FFDM and SFM.

A series of case selection criteria have been followed in the database construction and ground truth generating to make the number balance in mass size, normal case via abnormal case and the detection difficulty: (1) There are different size and different contrast level microcalcifications, and different shape of masses including irregular, circumscribed, microlobulate, obscured, ill-defined and spiculate as defined in BI-RADS. (2) A balanced distribution of benign and malignant lesions. (3) Normal cases will have at least two years clinical follow-up without cancer, which will not contain any benign findings or artifacts. The histograms of the frequency of occurrence versus the measured quantity will be generated to guide the selection of cases. (4) A balanced distribution of mass size for the training and testing databases.

3. Performance comparison of current CAD methods

3.1 Description of previously developed CAD system for detection and diagnosis of breast cancer

This CAD system has been developed in my mentor, Dr. Wei Qian's laboratory for several years using sound signal processing and engineering principles, which consists of several modules including: preprocessing, segmentation, feature extraction and selection, and classification. The brief description of each module is as follows while their detail description has been published in associated leading journals or international conferences.

Preprocessing module: This module includes noise suppression and image enhancement. Tree structured nonlinear filtering (TSF) was developed for image noise suppression and artifact reduction as required for implementation of high order wavelet transforms that are sensitive to noise. TSF is a three-stage filter designed with central weighted median filters (CWMFs) as subfiltering blocks applied to each pixel within the filter window. Modified windows for the filter bank in the first stage and comparison of the filtered image to the raw image in each stage was used to preserve image detail, such as parenchymal tissue structures, with significantly improved noise reduction compared with single stage filters as determined using simulated images with different noise levels and representative mammographic images.

To image enhancement, Directional wavelet transform (DWT) was developed for multiorientation signal decomposition using polar coordinates on a pixel by pixel basis. The selection of the wavelet basis functions is important for a high orientation selectivity. It is achieved by introducing a directional sensitivity constraint on the wavelet function. The input image is decomposed by the DWT, yielding two output images, the first is a directional texture image used for directional feature extraction, the second is a smoothed version of the original image with directional information removed and later used for image segmentation.

Segmentation module: a 2-chennel tree structured wavelet transform (TSWT) was developed combined with adaptive clustering (AC) for image decomposition and segmentation as an efficient multiresolution representation method. The lower resolution characteristics are useful for localization of the suspicious areas, while the information in the higher resolution is essential for fine detail, as required for mass margin feature extraction. Segmentation of the suspicious areas into two classes (fatty tissue/parenchymal tissue or suspicious masses) was performed by an adaptive clustering algorithm for the full mammogram, specifically for the wavelet transformed image as opposed to image gray scale approach.

Feature extraction and selection module: feature extraction in the gray level and morphological domain was performed, and then directional features were extracted from texture domain. This CAD module included contour tracing of the segmented region and extraction of the speculations for stellate lesions. A ray tracing (RT) algorithm was developed to determine features that included: (1) orientation of speculations and (2) the average normalized spiculation length based on mass size. These features were also added to the FBDT module to improve mass detection. Genetic algorithm has been employed for feature selection.

Classification: three-layer feed forward multistage artificial neural network (NN) was constructed combined with back-propagation learning algorithm with Kalman filtering as classifier of segmented suspicious areas with significantly increased convergence speed for more efficient classification.

3.2 Comparison of CAD system performance on FFDM and SFM

An objective means of assessing the performance of developed CAD system is very important for its evaluation with the proliferation of imaging methodologies and the containment of healthcare cost on everybody's mind. Computerized free-response receiver operating characteristic (FROC) has been employed in this study to evaluate the performance of CAD system. The CAD system described above has been tested using constructed test database. At least five pairs of TPF and average FPs have been computed and data has been fitted using the FROCFIT program. Table 1 shows performance of the CAD system on FFDM and SFM, respectively.

Table 1 Evaluation of CAD system before optimization

	FFDM		SFM	
	Mass	MCC	Mass	MCC
Sesitivity (%)	84.6	90.1	82.1	88.6
FP rate (/image)	3.9	1.6	3.3	1.2

The comparison results have shown that the performance of CAD system on FFDM is not different from that on SFM, neither better nor worse than that on SFM. The major reasons for this are that the previous developed CAD system was for SFM image with fixed or empirical parameter setting, sensitive to spatial resolution that is different between FFDM and SFM, and the whole system is not matched or not fully optimized based on the system. It does not express that the performance of CAD system on FFDM is better or worse than that on SFM based on current results. So the optimization of CAD system will also be for FFDM as planned in the proposal.

In reviewing the current developed CAD system, it has following characteristics:

(1) Its performance on SFM is good, but does not reach the requirement for clinical trial.
(2) It was developed for SFM images with empirical or fixed parameter setting.
(3) Parameters in the CAD system are not matched or the whole CAD system was not optimized to make it effective and robust.
(4) CAD modules need development or modification with adaptive method to make it robust and effective to different imaging paradigm and different resolution.

4. Development and modification of CAD modules for FFDM

It has been being worked on the development and modification of CAD modules for FFDM based on the analysis of the previous developed CAD system.

(1) A overall CAD system on FFDM for detection and diagnosis of breast cancer has been configured.
(2) Adaptive image preprocessing module has been constructed. Adaptive methods for automatic parameter selection and for selection of filter window sizes (from 3×3 to 7×7) depending on requirements for image detail preservation have been designed. This module can be uniquely modified for higher order N directional filter.
(3) Adaptive TSWT CAD module has been developed. The M-channel TSWT has the advantage that can be expanded to M×M different resolution information, generating M^2 subimages. The following methods are under development: (1) the use of different M channel wavelets to increase the choice for selection of M×M subimages that is supposed to improve suspicious area enhancement and subsequent segmentation, (2) adaptive selection of subimages using localized metrics to zoom into the desired features for mass enhancement.

REPORTABLE OUTCOME

1. Wei Qian, Xuejun Sun, Robert A Clark, "Multiresolution/multiorientation based nonlinear filters for image enhancement and detection in digital mammography", Journal of X-ray Science and Technology, No.9, 2002
2. Wei Qian, Xuejun Sun, Dansheng Song, and Robert A Clark, "Digital mammography: Wavelet Transform and Kalman Filtering Neural Network in Mass Segmentation and Detection", Academic Radiology, Vol. 8, No. 11, November 2001
3. Xuejun Sun, Wei Qian, "System Oriented Optimization of CAD for Mass Detection in Digital Mammography", Proceedings of International SPIE Conference on Medical Imaging, San Diego, Feb. 23-28, 2002

CONCLUSIONS

In the initial grant year, databases for training and testing of CAD system performance have been constructed and corresponding truth files have been generated for FFDM and SFM respectively. Performance of current CAD system for the detection and diagnosis of breast cancer has been retrospectively evaluated on FFDM and SFM images, respectively. CAD modules have been developed or modified for FFDM.

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